Factors influencing antibiotic prophylaxis for surgical site infection prevention in general surgery: a review of the literature

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Background: Surgical site infections (SSIs) are common surgical complications that can be prevented with antibiotic prophylaxis. Research shows poor adherence to guidelines for this practice. We conducted a scoping review to identify factors or interventions that influence antibiotic prophylaxis administration.

Methods: An investigator with informatics training searched indexed (MEDLINE, Cochrane Library) and nonindexed (Internet) sources from January 1996 to February 2007. Selected studies were English-language, peer-reviewed, quantitative or qualitative studies describing factors or interventions influencing adherence to SSI-prevention guidelines or SSI rates in general surgery. Two investigators independently reviewed citations and full-text articles and extracted data, and met to compare selections or data and resolve differences through discussion. We extracted data on type of surgery, study design, intervention or factors examined and key findings. We then examined the quantity and type of studies and their findings.

Results: Nineteen of 192 studies met the eligibility criteria. Seven studies investigated predictors of appropriate antibiotic use through descriptive or exploratory means. Twelve evaluated adherence to antibiotic prophylaxis recommendations by comparing patient cohorts before and after the introduction of quality-improvement strategies. Individual knowledge, attitudes, beliefs and practice; team communication and allocation of responsibilities; and institutional support for promoting and monitoring practice appear to influence practice.

Conclusion: Larger and multisite studies included in our review favour implementation of multidisciplinary pathways, individualized performance data and written or computerized order sets as quality-improvement strategies, but further research is warranted to more rigorously evaluate the effectiveness of these strategies on antibiotic prophylaxis practice.

Contexte : Les infections des plaies chirurgicales sont des complications fréquentes de la chirurgie qu'il est possible de prévenir grâce à l'antibioprophylaxie. La recherche fait état d'une faible conformité aux directives à cet égard. Nous avons procédé à une étude exploratoire afin de relever les facteurs ou les interventions qui influent sur l'administration de l'antibioprophylaxie.

Méthodes : Un investigateur formé en informatique a interrogé les sources pertinentes indexées (MEDLINE, base de données Cochrane) et non indexées (Internet) entre janvier 1996 et février 2007. Les études sélectionnées étaient de langue anglaise, révisées par les pairs, quantitatives ou qualitatives, et décrivaient les facteurs ou interventions susceptibles d'influer sur la conformité aux directives de prévention des infections de plaies chirurgicales ou sur les taux de ces infections en chirurgie générale. Deux investigateurs ont parcouru les citations et les articles complets chacun de leur côté pour en extraire les données. Ils se sont ensuite rencontrés pour comparer les sélections ou les données et résoudre les différences par voie de discussion. Nous avons extrait les données sur le type de chirurgie, le protocole des études, les interventions ou facteurs examinés et les principales conclusions. Nous avons ensuite analysé le nombre et le type d'études et leurs conclusions.

Résultats : Nous avons retenu 19 études sur 192 qui répondaient aux critères d'admissibilité; 7 études citaient les prédicteurs de l'utilisation appropriée des antibiotiques par méthode descriptive ou exploratoire et 12 analysaient la conformité aux recommandations relatives à l'antibioprophylaxie en comparant des cohortes de patients avant et après l'instauration de stratégies d'amélioration de la qualité des soins. La pratique semble influencée par les connaissances, les attitudes, les croyances et la pratique, de même que par la communication et la répartition des responsabilités

au sein des équipes et le soutien qu'offre l'établissement à la promotion et à la surveillance des pratiques.

Conclusion : Les études multicentriques de plus grande envergure incluses dans notre analyse préconisent la mise en place d'approches multidisciplinaires, le recensement de données de rendement personnalisées et l'application de protocoles imprimés ou informatisés comme stratégies pour l'amélioration de la qualité des soins, mais il faudra procéder à d'autres études pour évaluer plus rigoureusement l'impact de ces stratégies sur les pratiques en matière d'antibioprophylaxie.

Surgical site infections (SSIs) are the most common complication following surgery. As many as 1% of patients undergoing clean (e.g., breast, hernia) and 11% of patients undergoing clean-contaminated (e.g., colorectal) surgery experience SSIs.[1] They are problematic for patients owing to pain, delayed wound healing, delay of subsequent treatment, time lost from work and, rarely, death. For the institutions providing care, SSIs contribute to increased costs owing to longer hospital stays, readmissions and additional use of antibiotics that can lead to antibiotic-resistant bacteria. Patients who experience SSIs are up to 60% more likely to spend time in the intensive care unit, 5 times more likely to be readmitted to hospital and twice as likely to die compared with patients without an SSI.[2] Care for patients with SSIs was estimated to cost, on average, US$5155 compared with US$1733 for those with an uncomplicated postoperative course.[3]

Meta-analyses demonstrate that antibiotic prophylaxis is the most effective strategy for preventing SSIs following breast,[4,5] appendix[6,7] and colorectal surgery,[8,9] but there is no associated risk reduction for herniorraphy, hernioplasty or laparoscopic cholecystectomy.[10–12] Guidelines for SSI prevention have been developed in Europe, the United Kingdom, Australia, the United States and Canada.[13–22] Recommendations common to these protocols include appropriate selection of antibiotics according to type of surgery, administration within 1 hour before surgical incision, discontinuation within 24 hours of surgery, hair removal only if necessary by clipping or depilatory creams and maintenance of body temperature and serum glucose levels in the normal range (Table 1).

More contemporary evidence has challenged previously held beliefs about the effectiveness of some commonly used interventions for preventing SSIs. For example, a meta-analysis of 6 trials involving 10 007 patients undergoing biliary tract, hernia, breast, vascular and urologic surgery found that bathing with chlorhexidine antiseptic solution did not reduce SSI rates compared with placebo or bar soap.[23] A meta-analysis of 11 trials involving 5031 patients undergoing a variety of surgical procedures found no difference in SSI rates among patients with or without preoperative hair removal.[24] If hair removal is necessary, clipping or depilatory creams result in fewer SSIs than shaving with a razor. Another meta-analysis of 9 trials involving 1592 patients undergoing colorectal surgery revealed that mechanical bowel preparation did not reduce the risk of SSIs but increased the rate of anastomotic leakage compared with no bowel preparation.[25] Other interventions previously thought to reduce the risk of SSIs (e.g., use of disposable face masks, removal of rings and nail polish in the operating room), have been discounted with more recent evidence.[26,27]

Despite the availability of these guidelines, there is considerable evidence that antibiotics are used excessively and inappropriately for the prevention of SSIs.[28–38] Few studies have examined SSI-prevention practices in Canada. A study of 103 colorectal surgery patients at one hospital in Alberta found that 5% (5/96) of patients received appropriate preoperative antibiotic administration.[39] In 352 patients

Table 1. Summary of common recommendations for surgical site infection prevention promoted by practice guidelines or professional consensus

	Organization									
Recommendation	JCAHO*	SCIP	CDC	ACS	IHI†	NHS	SIGN	Europe‡	Australia§	Canada¶
Appropriate selection of antibiotic	√	√	√	√	√	√	√	√	√	√
Receipt within 1 h before surgical incision	√	√	—	—	√	√	√	√	√	√
Discontinuation within 24 h	√	√	—	—	√	√	√	√	√	√
Appropriate hair removal (no shaving)	√	√	√	√	√	√	—	—	√	√
Body temperature maintenance (colorectal)	√	√	—	—	√	√	—	—	√	√
Glucose level maintenance (cardiac)	√	√	√	√	√	√	—	—	—	—

ACS = American College of Surgeons;[16] CDC = Centers for Disease Control and Prevention;[15] IHI = Institute for Healthcare Improvement;[17] JCAHO = Joint Commission on Accreditation for Healthcare Organizations;[13] NHS = National Health Service;[18] SCIP = Surgical Care Improvement Project;[14] SIGN = Scottish Intercollegiate Guidelines Network.[19]
*Based on SCIP.
†100 000 Lives Campaign.
‡Several professional associations taking part in Surgical Infections: Prevention and Management, Moscow.[20]
§Australian Council for Safety and Quality in Health Care.[21]
¶Safer Healthcare Now! Campaign.[22]

undergoing surgery for hip fractures at 22 hospitals in 1990, only 30% received appropriate preoperative antibiotic administration, and the period of administration was more than 24 hours in 78% of those patients.[40] The Canadian Adverse Events Study found that surgical infections were the most common hospital-based adverse event and that such events were more common in teaching than community hospitals.[41] As a result of this study, the Safer Healthcare Now! initiative was launched.[22] Patterned after the Institute for Healthcare Improvement's 100 000 Lives Campaign, the Safer Healthcare Now! initiative strives to encourage Canadian health care organizations to implement 6 targeted interventions, 1 of which is the prevention of SSIs.

Given the considerable burden of disease represented by SSIs and the widespread lack of adherence to guidelines for antibiotic prophylaxis, quality-improvement efforts are necessary. To determine which tools or strategies could most effectively be used to modify current practice patterns, it is important to first understand the multiple possible factors that influence the use of prophylactic antibiotics. Research indicates that numerous factors can interact to influence awareness of, agreement with, adoption of and adherence to guideline recommendations apart from patient and individual provider characteristics, including the setting or context of care; institutional and system constraints; and the nature of the knowledge, process or technology itself.[42]

The purpose of the present study was to conduct a systematic review of the medical literature and identify modifiable factors or interventions that have been found to influence antibiotic prophylaxis for SSI-prevention practices in general surgery as the first part of a quality-improvement effort at a network of 7 Canadian academic hospitals. This information would form a framework by which to evaluate the organization and delivery of antibiotic prophylaxis at baseline, identify opportunities for quality improvement, guide the selection of interventions that may be required to improve compliance with guideline recommendations and reduce SSI rates, and reveal gaps in the research literature that could be addressed through further evaluation of novel interventions.

Methods

Approach

We conducted a scoping review to provide decision-makers involved in planning SSI-prevention initiatives with information about the extent and nature of research on factors or interventions influencing this practice.[43] This approach is increasingly the method of choice when a topic is complex or has not been reviewed comprehensively before. The findings are used to determine whether sufficient literature exists to conduct a full review, or whether gaps in knowledge exist such that further primary research is necessary. A traditional systematic review generally addresses a specific question with a relatively narrow range of quality-assessed studies identified through an exhaustive search of many sources. A scoping review is conducted with comparable rigor to a systematic review, but examines a broader question by reviewing a wide range of study designs without considering the quality of individual studies. It can therefore be completed within a shorter timeframe, as required for rapid-cycle quality improvement.

Data collection

An investigator with informatics training (A.R.G.) conducted the searches with guidance from the study team. The investigator searched MEDLINE from January 1996 to February 2007 using medical subject headings (i.e., "surgical wound infections, prevention and control" AND "physicians practice patterns or quality of care" or "outcome and process assessment [health care]" or treatment outcome or "outcome assessment [health care]" or "process assessment [health care]" or program evaluation or quality assurance, health care or benchmarking or guideline adherence or diffusion of innovation or intervention studies). The most recent 10-year period was specified since international SSI-prevention guidelines were introduced during this time. The investigator searched the Cochrane Library using the term "surgical wound infections," but this search did not reveal any relevant citations. We also considered the nonindexed grey literature by searching international government and research agency websites using the keywords "surgical site infections" or "surgical wound infections." The websites included those of departments of health in Australia, Canada, the United Kingdom and United States; the Agency for Health Research and Quality; and the Institute for Healthcare Improvement. Since a scoping review is a preliminary investigation to assess whether sufficient evidence exists for a full review, we specifically did not follow citations within selected items, manually search the tables of contents of relevant journals or consult with colleagues or experts to identify additional items not identified by literature search.

Eligible studies included English-language articles that quantitatively (e.g., compliance before–after an intervention; cohort study examining association of various factors on compliance; surveys to examine knowledge, attitudes, beliefs and practice) or qualitatively (e.g., interviews, document analysis related to compliance with SSI-prevention guidelines) described factors associated with the use of antibiotic prophylaxis for SSI prevention in elective general surgical procedures or interventions designed to improve the use of antibiotic prophylaxis or reduce SSI rates and provided sufficient detail to enable extraction of data on study design, methods and outcomes. To understand relevant factors in the Canadian health system context, we included studies conducted in Canada that may have focused on operative procedures other than general surgery. We excluded

abstracts, letters, commentaries, editorials, non–peer reviewed literature and studies on the clinical effectiveness of therapeutic interventions for SSI prevention.

To minimize selection bias, 2 investigators (A.R.G., D.F.) independently reviewed the search results and selected articles for possible inclusion based on the eligibility criteria. The investigators then met to compare selections and resolve differences through discussion. Once the selected items were available, 2 investigators (A.R.G., C.E.) independently reviewed the full-text articles, selected items according to eligibility criteria and then met to compare selections and achieve consensus on inclusions.

Data analysis

Two investigators (A.R.G., C.E.) extracted data on the type of surgery, study design, intervention or factors examined and key findings, tabulated the data independently and then met to compare and discuss their findings. We did not undertake a detailed quality assessment of individual studies because our goal was to identify all potential factors or interventions influencing SSI-prevention practice from various types of studies rather than analyze or pool the results of these studies. Instead, we addressed the quality of the evidence base by commenting on the number, type and size of studies and whether controls were included.

We examined tabulated findings to discuss the quantity and type of studies identified. We then synthesized the findings to highlight key factors that have been found to influence antibiotic prophylaxis for SSI-prevention practices and possible tools or intervention strategies that improved compliance with recommended practice and associated outcomes.

RESULTS

We identified 187 citations in MEDLINE and the Cochrane Library and 5 additional items in the grey literature search. From these citations, 2 investigators independently selected a total of 42 relevant items. The 140 unselected items were not empirical studies, did not focus on general surgery procedures or examined clinical interventions for SSI prevention and were therefore considered ineligible. On comparing their selections of the 42 relevant items, the 2 investigators agreed on the inclusion of 11 and the exclusion of 3, and they disagreed on 28 citations. Through discussion they resolved to include 8 citations and exclude 20 citations, which were not topically relevant (n = 13) or reported findings from other studies (n = 7). Nineteen full-text articles met the eligibility criteria and were included in the review.

Of the included studies, 3 investigated predictors of appropriate antibiotic use through analysis of observational data, and all found that use of written orders, particularly those implemented in the operating room, predicted appropriate timing of antibiotic prophylaxis, regardless of whether the study was retrospective or prospective (Table 2).[40,44,45] Two of these studies are notable for their examination of predictive factors across multiple sites. A retrospective cohort study involving 8137 patients undergoing clean and clean-contaminated surgeries at 108 Veterans Administration hospitals found that administration of antibiotics in the operating room significantly improved adherence to recommendations for timing of prophylaxis.[46] Another retrospective cohort study of 352 patients having hip fracture surgeries at 22 hospitals across Canada found that written orders were associated with appropriate timing of antibiotic prophylaxis.[40] A single-institution prospective cohort of 4441 patients undergoing clean and clean-contaminated surgeries demonstrated that both written orders and an operative checklist significantly improved antibiotic administration.[45]

Three studies attempted to identify provider or institutional factors influencing antibiotic prophylaxis for SSI prevention using survey methods (Table 3). A single exploratory study involving qualitative analysis of interviews with surgeons, anesthesiologists and operating room administrators at 2 teaching hospitals in Canada revealed that individual health care professionals felt that attention to antibiotic prophylaxis ranked lower than their many other priorities.[46] Conflicts in perceived roles and responsibilities among team members and organizational workflow

Table 2. Factors influencing antibiotic prophylaxis for surgical site infection prevention

Study	Surgery	Design	Findings
Hawn et al.[44]	Clean and clean-contaminated surgery	Retrospective cohort of 8137 patients at 108 VA hospitals: factors associated with timely antibiotic prophylaxis administration	Early dosing accounted for 79% of untimely prophylaxis. Antibiotic administration in the operating room influenced timely prophylaxis (OR 7.74, 95% CI 6.49–9.22)
Turnbull et al.[45]	Clean and clean-contaminated surgery	Prospective cohort of 4441 patients in single tertiary care hospital to assess health system factors influencing appropriate administration of antibiotic prophylaxis	Appropriateness of first dosing improved with written orders (OR 19.7, 95% CI 9.1–42.7, $p < 0.001$) and orders given in the operating room (OR 13.9, 95% CI 7.5–25.6, $p < 0.001$); it was reduced with same-day surgery (OR 0.57, 95% CI 0.4–0.82, $p < 0.001$)
Zoutman et al.[40]	Clean surgery (hip-fracture surgery)	Retrospective cohort of 352 patients having surgery at 22 hospitals across Canada in 1990 to assess surgical and organizational factors influencing timing of antibiotic prophylaxis	Lack of a written order, being a nonteaching hospital and shorter duration of surgical procedure were predictive of inappropriate antibiotic prophylaxis

CI = confidence interval; OR = odds ratio; VA = Veterans Administration.

patterns for admitted and same-day surgery patients influenced the delivery of antibiotic prophylaxis. Another study surveyed representatives of infection-control programs at 172 hospitals across Canada and reported that 60% provided physicians with infection-control education and 37% provided individual physicians with SSI data.[47] Another survey of surgeons in Australia revealed limited knowledge of SSI-prevention guidelines and concerns about the accuracy of SSI performance data.[48]

Thirteen investigations evaluated interventions for improving compliance with antibiotic prophylaxis recommendations by comparing patient cohorts of clean and clean-contaminated surgical patients before and after the introduction of quality-improvement strategies (Table 4).[49–61] Three of these studies are notable for being carried out across multiple institutions or involving a large number of patients at a single institution and demonstrating improved antibiotic prophylaxis practice and outcomes. One of these studies examined the impact on 47 581 patients of delivering individualized performance data to surgeons and operative and surgical ward staff at 1 hospital.[54] A study involving 35 543 patients in 44 hospitals examined the effect of quality-improvement cycles involving education, reminders and sharing of information among multidisciplinary teams across sites.[56] Another study evaluated changes in the timing of prophylaxis for 162 196 surgical patients at 1 hospital after the introduction of a clinician-derived consensus protocol.[61] Implementation of a hospital protocol for antibiotic prophylaxis significantly reduced SSI rates or enhanced adherence to antibiotic prophylaxis recommendations in several additional single-institution studies involving a range of 583–1353 patients.[52,55,58,60]

There was no significant decrease in SSI rates among 3620 patients at 12 hospitals that adopted a restrictive antibiotic prophylaxis policy.[50] This finding is consistent with a single-institution study included in our review that reported SSI rates did not change among 12 299 patients as a result of reduced access to extra antibiotic doses.[51] In contrast, 2 single-hospital intervention studies demonstrated improved adherence to antibiotic prophylaxis based on restrictive medication policies involving either an automatic-stop prophylaxis form or the preparation of individualized patient prophylaxis kits by the pharmacist.[49,53]

Collectively, these investigations identify individual (i.e., knowledge, attitudes, beliefs, behaviour), team (i.e., culture, communication, workflow) and organizational (i.e., protocols, policies, integrated systems) factors that constitute a framework by which to evaluate compliance with antibiotic prophylaxis for SSI prevention and plan quality-improvement programs. Our review also suggests several strategies or interventions that appear to improve antibiotic prophylaxis, including

- providing education or individualized performance feedback to address clinician knowledge, attitudes, beliefs and behaviour;
- establishing multidisciplinary protocols or pathways to influence team-level communication and workflow by specifying timing and sequence of responsibilities; and
- implementing institutional antibiotic prophylaxis programs involving integrated systems to reduce, curtail or control the administration of antibiotics through computerized decision-support programs, written orders or pharmacist preparation of individualized kits.

Discussion

We conducted our scoping review of 19 studies to identify modifiable factors and interventions that have been found to influence perioperative prophylactic antimicrobial administration and to assess this evidence to determine whether further research is necessary. As we hypothesized, numerous factors may interact to challenge appropriate antibiotic administration, including individual knowledge, attitudes, beliefs and practice; team communication and allocation of responsibilities for antibiotic prophylaxis; and institutional support for promoting and monitoring antibiotic prophylaxis.[42] Our findings can be used by others as a framework by which to conduct an environmental assessment in their own practice settings. Environmental assessment is the first step in implementing new practices and is a more holistic, proactive approach to quality improvement than continuing education because it considers the many

Table 3. Surveys of factors influencing antibiotic prophylaxis for surgical site infection prevention

Study	Design	Findings
Tan et al.[46]	Interviews with surgeons (11), anesthesiologists (12) and OR administrators (4) at 2 teaching hospitals exploring factors influencing timing of antibiotic prophylaxis administration	Despite knowledge of the guidelines, interviews revealed individual (low priority), team (tension in perceived roles and communication, confusion regarding actual administration) and organizational barriers (trend to same-day admissions, combined with previous factors, often resulted in late administration, even after surgery had commenced)
Macbeth et al.[47]	Postal survey of all surgeons in Queensland, Australia, to assess knowledge, attitudes and beliefs regarding accuracy and usefulness of SSI data and opinions on acceptable rates of SSIs	Surgeons were not familiar with recommendations set by the Australian Council on Healthcare Standards and thought data on SSI rates would be more useful if criteria defining infection were standardized and data were adjusted for other parameters to improve accuracy
Zoutman et al.[48]	Survey of infection-control programs at 172 Canadian hospitals on reporting of SSIs to individual health care providers	There was fewer than 1 infection control professional per 250 beds in 42% of hospitals, 60% of infection control programs involved physicians or other health professionals with infection control training, and SSIs were reported to individual physicians in 36.8% of hospitals

OR = operating room; SSI = surgical site infection.

Table 4. Interventions influencing antibiotic prophylaxis for surgical site infection prevention

Study	Surgery	Design	Findings	
			SSI rates	Adherence with antibiotic prophylaxis guidelines
Gomez et al.[49]	Clean and clean-contaminated surgery	Cohort study with 7478 patients at 1 teaching hospital before–after "automatic-stop" prophylaxis form	Reduced SSI rates (RR 0.59, 95% CI 0.44–0.79, $p < 0.01$) and reduced costs (US$10 678.66 v. 7686.05/per 1000 patient d, RR 0.87, 95% CI 0.86–0.89, $p < 0.01$)	Improved timing (RR 0.27, 95% CI 0.25–0.30, $p < 0.01$), improved appropriateness (RR 0.50, 95% CI 0.45 to 0.55, $p < 0.01$), improved duration of antibiotic prophylaxis (RR 0.80, 95% CI 0.77 to 0.84, $p < 0.01$)
Mannien et al.[50]	Clean and clean-contaminated surgery	Cohort study with 3621 patients at 12 hospitals before–after a more restrictive antibiotic prophylaxis policy	No significant decrease in SSI rate (5.4% to 4.5%, $p = 0.22$)	—
Fonseca et al.[51]	Clean and clean-contaminated surgery	Cohort study of 12 299 patients at single tertiary care hospital before–after educational presentation encouraging 1-dose antibiotic prophylaxis and reduced access to extra antibiotic doses	Rate of SSI did not change (2% v. 2.1%, $p = 0.67$)	Compliance with 1 dose was high at 6123/6159, 99%
O'Reilly et al.[52]	Clean and clean-contaminated surgery	Cohort study at a single hospital in 2003 before–after anesthesia clinical information system implemented practice guidelines and generated provider-specific performance reports (no. patients not provided)	—	Increased number of patients receiving antibiotic prophylaxis within 1 h of surgical incision from 69% to 92% 1 yr later
Carlès et al.[53]	Clean and clean-contaminated surgery	Double prospective cohort study with 420 patients at a single hospital matched by type of surgery comparing personalized antibiotic prophylaxis kit prepared by pharmacist, including instructions for dose, timing and duration v. usual care (freely prescribed by anesthesiology)	—	Personalized kits improved compliance with guidelines for antibiotic prophylaxis (82% v. 41%, $p < 0.001$), improved timing of administration (12% v. 24%, $p = 0.003$) and improved duration (1.5% v. 22%, $p < 0.001$)
Sykes et al.[54]	All adult surgery excluding burns and day surgery	Cohort study with 47 581 patients at single teaching hospital before–after active SSI surveillance program, including provision of performance data to surgeons, OR staff and surgical ward staff every 6 mo	In-hospital SSI rates declined over 12-yr period (4.7% to 1.2%, $p < 0.001$*)	—
Alerany et al.[55]	Clean and clean-contaminated surgery	Cohort study with 586 patients at a single ambulatory surgical centre before–after introduction of a multidisciplinary protocol featured in the OR and design of surgery-specific medication sets	—	Appropriateness of antibiotic prophylaxis increased from 50.9% to 94.9%, $p < 0.001$
Dellinger et al.[56]	Clean and clean-contaminated surgery	Cohort study with 35 543 patients at 44 hospitals before–after education, reminders and multidisciplinary team information sharing and quality-improvement cycles	Reduced SSI rates (2.28% to 1.65% between first and last quarter in 12-month period ($p < 0.001$)	Performance improved for timing of antibiotic prophylaxis, appropriateness of antibiotic selection, discontinuation of antibiotic, normothermia, no shaving, supplemental oxygen and glucose control from 3% to 27%
Geubbels et al.[57]	Clean-contaminated surgery	Cohort study at a single hospital before–after feedback surveillance data to surgeons every 6 mo	Reduced SSI rates (4.9% to 3.6%, 95% CI 2.7%–19.9%)	Proportion of patients receiving antibiotic prophylaxis increased from 33% to 81% after 18 mo
Brusaferro et al.[58]	Clean and clean-contaminated surgery	Cohort study with 723 patients at a single teaching hospital before–after introduction of a protocol for antibiotic prophylaxis	—	Appropriateness of antibiotic prophylaxis increased from 30.8% to 45.2%, $p < 0.01$
Reilly et al.[59]	Clean and clean-contaminated surgery	Cohort study with 1772 patients at a single hospital before–after introducing a surveillance program involving a full-time nurse auditing each surgical case	Reduced rate of SSI (13.9% to 7.9%, $p = 0.05$)	—
Neumayer et al.[60]	Clean and clean-contaminated surgery	Cohort study with 1353 patients at a single VA hospital before–after introducing a protocol for antibiotic prophylaxis	Reduced rate of SSI (5.5% to 2.9%, $p = 0.49$)	—
Pestotnik et al.[61]	Clean and clean-contaminated surgery	Cohort study of 162 196 patients discharged from a single teaching hospital before–after clinician-derived consensus guidelines were embedded within a computer decision-support program	—	Appropriateness of timing increased from 40% in 1988 to 99.1% in 1994

CI = confidence interval; OR = operating room; RR = risk ratio; SSI = surgical site infection; VA = Veterans Administration.
*Rates rose, then fell again when program was reinstituted following a 15-month suspension from 1990 to 1992.

multilevel factors that must be addressed.[62] For example, individual knowledge, attitudes, beliefs and team-related issues could be assessed using a self-report questionnaire. Institutional support for and initiatives related to SSI prevention could be identified through interviews with health professionals, including managers responsible for infection prevention and control, quality improvement and patient safety. Concordance of existing policies or protocols with antibiotic prophylaxis guidelines could be established through content analysis of these resources.

Our study revealed several strategies that appear to improve compliance with antibiotic prophylaxis recommendations and reduce SSI rates. Three large and/or multisite observational studies suggest that written orders used in or specifying delivery of antibiotics in the operating room promote appropriate timing of antibiotic delivery, and 5 before–after single-institution observational studies, 1 involving 162 196 patients, suggest that antibiotic prophylaxis is better used as a result of introducing institutional protocols or guidelines. Two additional before–after observational studies involving 47 581 and 35 543 patients, respectively, found that individualized performance data and a multidisciplinary strategy involving education and reminders improved antibiotic prophylaxis.

Our study is limited by the fact that we may have failed to find all relevant published research on factors that influence adherence with antibiotic prophylaxis for SSIs; however, a scoping review is meant to be a preliminary investigation that produces recommendations for ongoing research. Interpretation of the findings is limited by the nature of these studies. Prospective or retrospective cohort studies involved patients undergoing a variety of surgical procedures for different indications and did not distinguish among these during data analysis. Most of the reviewed studies involved data analysis before and after the introduction of an intervention and failed to control for the intervention or match patients by type of surgery. Uncontrolled before–after studies are weak evaluative designs that are known to overestimate the effects of quality-improvement interventions.[63] Given the few studies included in our review that had weak designs, mixed patient populations and inconsistent application of interventions, it was not possible to pool results, and conduct of a more thorough systematic review is not likely to yield further useful information. Ideally, randomized controlled trials or case–control studies are needed to thoroughly describe and more definitely demonstrate the effectiveness of these interventions compared with no intervention or among each other.

Considerable research has been conducted to establish the effectiveness of various strategies for facilitating the uptake of innovations into practice, including education, guidelines, decision-making tools that foster teamwork or are embedded at the point-of-care and incentives such as performance data.[64–67] Ongoing studies to evaluate the effectiveness of these promising interventions for antibiotic prophylaxis could draw upon this research to design the interventions and establish measures of impact. Educational meetings are known to have a small effect on practice, but adult learning theory suggests their impact could be greater if they were interactive rather than didactic, sequential and based on work-situated issues and if the participants were engaged in planning and implementation.[68] The outcome of educational meetings can be further enhanced through structure and content that triggers recognition among individuals that their practices do not conform to that of their peers or accepted standards. Called cognitive dissonance, this can be accomplished by setting clear objectives related to knowledge, attitudes, beliefs and behaviour so that subsequent action is understood and by creating opportunities for self- or team-reflection either before, during or after the event.[69] Another promising strategy to complement educational initiatives and promote behaviour change involves requesting that each participant sign a commitment to change agreement specifying a target behaviour or outcome and an associated time period.[70] Follow-up with individuals not only reinforces their behaviour, but also enables the collection of data on unanticipated barriers.

Clinicians are more likely to comply with guidelines when they have been involved in developing the recommendations.[65] One way to engage health professionals in guideline development and implementation is to translate practice recommendations into a protocol or pathway that specifies and coordinates responsibilities and timing for particular actions among a multidisciplinary team.[71] There is now a substantial body of evidence that effective teamwork in health care contributes to improved quality of care for patients and organizations.[72] A review of health care teamwork literature from 1985 to 2004 suggests that factors associated with team structure such as diversity of clinical expertise involved in team decision-making largely account for improvements in patient care and that team processes such as collaboration and coordination are most likely to influence team effectiveness.[73] The introduction of pathways has improved patient outcomes and reduced hospital costs for various surgical procedures,[74,75] and a systematic review has demonstrated that 64% of computerized decision-support systems in which guidelines for diagnosis, drug prescribing and disease management were embedded resulted in improved performance.[76] Another way to engage stakeholders and improve adherence with guideline recommendations is to distribute performance data. Meta-analysis of controlled studies examining the effectiveness of audit and feedback have shown that data must be individualized and provided in-person by a respected colleague or superior at regular intervals.[77] This is because awareness of personal practice is considered to be actionable and triggers a response.[78]

Based on our scoping review, the value of antibiotic restriction remains unclear. This is not unexpected since

research shows that a single dose of antibiotics is just as effective as multiple doses for most patients and since there is little difference in effectiveness between different types of first- and second-line antibiotics that are commonly used.[79] However, antibiotic restriction may prevent some patients from appropriately receiving additional doses depending on factors such as length of surgery, which cannot always be predicted in advance. Thus, ongoing research should focus on the other types of interventions discussed in this review.

In conclusion, several individual-, team- and institution-level factors could potentially be modified to improve adherence with antibiotic prophylaxis recommendations and reduce SSI rates. Further research is warranted to more rigorously evaluate the effectiveness of various strategies for doing so, but interventions that appear promising include multidisciplinary protocols or pathways, individualized performance data and written or computerized order sets. Such studies would contribute to a greater understanding of how organizational structures and processes enable quality improvement — information that is currently lacking.

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Contributors: Drs. Gagliardi, Fenech, Nathens and McLeod designed the study. Drs. Gagliardi, Fenech and Eskicioglu acquired the data, which Drs. Gagliardi, Fenech and McLeod analyzed. Drs. Gagliardi and Fenech wrote the article, which all authors reviewed and approved for publication.

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